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DEVELOPMENT OF TOXIC SCREENING MODELS FOR SURFACE WATER SUPPLIES

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ABSTRACT: A major interest of the U.S. Environmental Protection Agency has been the assessment or ranking of vulnerable water utilities. Until recently, no techniques have been available that quantitatively put into perspective the many often conflicting factors that contribute to a utility's vulnerability to point and nonpoint sources of pollution. This paper describes a methodology, using two case studies, that enables such analyses and to also close the information gap that potentially exists between water pollution control strategies and water consumption.

INTRODUCTION

The Toxic Screening Models, described in this paper, provide an approach for identifying and assessing the pollutants that are likely to be present in surface waters used as water supplies. Specific uses of these models include the following:

- identification and assessment of communities whose water supplies could be vulnerable to synthetic organics resulting from industrial and muncipal discharges, or urban and agricultural runoff.
- design and implementation of a water quality monitoring program
- other water resource planning efforts requiring information on the water quality of surface waters.

Through the use of two case studies, the utility of a model-based technology for screening the types and concentrations of contaminants that might exist at any point along a stream system was applied. The case studies were conducted for (1) the Lower Mississippi River in the vicinity of the City of New Orleans, and (2) the Ohio and Kanawha Rivers between Charleston, West Virginia, and Cincinnati, Ohio.

LOWER MISSISSIPPI RIVER CASE STUDY

A preliminary study was performed to evaluate the application of the Routing and Graphical Display System developed by USEPA to show how

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computer-based modeling and simulation can be used to assess the types and concentrations of contaminants that might exist in the Lower Mississippi River (2). The approach used for determining the extent of these contaminants may be applied to other major river systems.

Additionally, water monitoring data available from a USEPA research project in Jefferson Parish, Louisiana were used to develop a supplemental data base(3). These data were used in combination with daily stream flow and suspended sediment measurements distributed by the U.S. Geological Survey.

The Routing and Graphical Display was used in two modeling approaches: (A) a downstream-directed analysis; and (B) an upstream directed analysis. The downstream-directed analysis involved the calculation of the concentration profiles for a range of contaminants based on: the estimated quantity of contaminant discharged at specified locations; the flow regime(s) in the river; and the value of the disappearance coefficient. The upstream-directed analysis involves calculating the concentration profile for a contaminant based on: the concentration of the contaminant at a selected downstream point; the flow regime(s) in the river; and the value of the disappearance coefficient. The upstream-directed analysis was used with the Jefferson Parish data to describe estimates of upstream conditions that would be consistent with the observed contaminant concentrations. Both approaches incorporated dilution effects (based on a mass balance technique) and disappearance effects (a first order decay function).

Twelve organic contaminants were used for comparison of simulated concentrations to observed concentrations. These compounds were: dichloromethane, chloroform, carbon tetrachloride, 1,2-dichloroethane, trichloroethene, tetrachloroethene, benzene, toluene, bis(2-ethyl hexyl) phthalate, fluorene, phenol, and nitrobenzene.

Downstream-Directed Analysis

An application of the downstream-directed influence line approach for 1,2-dichloroethane to the highly industrialized stretch of the river between Baton Rouge and New Orleans is presented as an example in Figure 1. The impact of the assumed disappearance rate and flow is illustrated. At average flow the travel time for the 130 mile strech of river is less than three days. During this short period of time, the disappearance rate has relatively little impact on contaminant concentrations. The travel time increases to 5.5 days under low flow conditions, thus increasing the residence time and as a result the sensitivity of the contaminant concentration to the value of the disappearance rate.

The quantity of streamflow generates two conflicting impacts on the contaminant concentration profiles. Higher flows provide greater dilution capacity and result in lower contaminant concentrations. However, higher flows produce increased velocity and a concomitant reduction in residence time, which results in less disappearance and higher relative pollutant concentrations for an assumed disappearance coefficient. This phenomenon is more significant under high disappearance coefficients.

At a disappearance rate of zero (i.e., a conservative constituent), the resulting profiles reflect only the increased dilution effect of higher flows. At river mile 140, the ratio of dichloroethane concentra-

tion at low flow to average flow is approximately 4.5:1 (Figure 1). At a disappearance rate of 0.2 days $^{-1}$, the counteracting impact of decreased residence time results in a concentration ratio (low flow: average flow) of approximately 3:1 for dichloroethane.

Upstream-Directed Analysis

The results of the upstream-directed influence line approach for a 10 ug/L contaminant concentration at Jefferson Parish are illustrated in Figure 2. Figure 2 illustrates the impact of the decay rate from Baton Rouge to New Orleans. The flow representations for both average and low flow are constant within this length of river; thus, there is no change in dilution capacity illustrated in Figure 2. The concentration profiles in Figure 2 are a result of varying disappearance rates and the effect of differences in travel times between low and average flow. As discussed previously, the greatest difference in concentrations between average and low flow occur at the highest disappearance rate. In this reach, average and low flow concentrations at K=0 are the same. As the disappearance rate decreases, the effect of more distant contaminant loading increases. Taken in the extreme, at a disappearance rate of zero (conservative contaminant), a contaminant discharged into the Missouri River in Montana has the same impact on water quality at New Orleans as does a contaminant discharged at Baton Rouge.

OHIO RIVER CASE STUDY

This analysis used the downstream-directed approach similar to the Lower Mississippi River analysis (1). In this case, QUAL-II a water quality simulation model, was used to spatially organize flow, discharge and stream dynamics data and to simulate the types and concentration of contaminants that might exist in the Ohio River. Additionally, in this study, potential impact on public health for cities exposed to the simulated pollutant concentrations was assessed. The pollutant concentrations were compared to the Water Quality Criteria, which only suggest at this time the concentrations of various pollutants that could be harmful to human health (4). The criteria take into account toxicity, carcinogencity or organolepticity (taste and odor) of the pollutants.

With the use of QUAL-II, the applicable priority pollutants discharged in the case study area (81 out of the 129 priority pollutants) were simulated for average, high and low flow conditions. For toxic and organoleptic pollutants, the flow scenarios are critical in determining whether a Water Quality Criteria has been exceeded. Because vulnerability to carcinogens is evaluated over years of exposure to pollutants in the drinking water, carcinogenic risk levels were intially estimated only at average flow. In the event of a spill, however, the flow characteristics can be important even to carcinogens, since very high concentrations of carbon tetrachloride, for example, can have an acute health effect.

Only 2 of the 11 organoleptic pollutants simulated exceeded a level at which sensitive consumers would be affected. Simulated concentrations of mercury, cadmium, chromium and lead exceeded values that could be harmful to more susceptible consumers such as the very old, very young, pregnant, or ill. During low flow mercury exceeded the the guidelines at a few of the utilities.

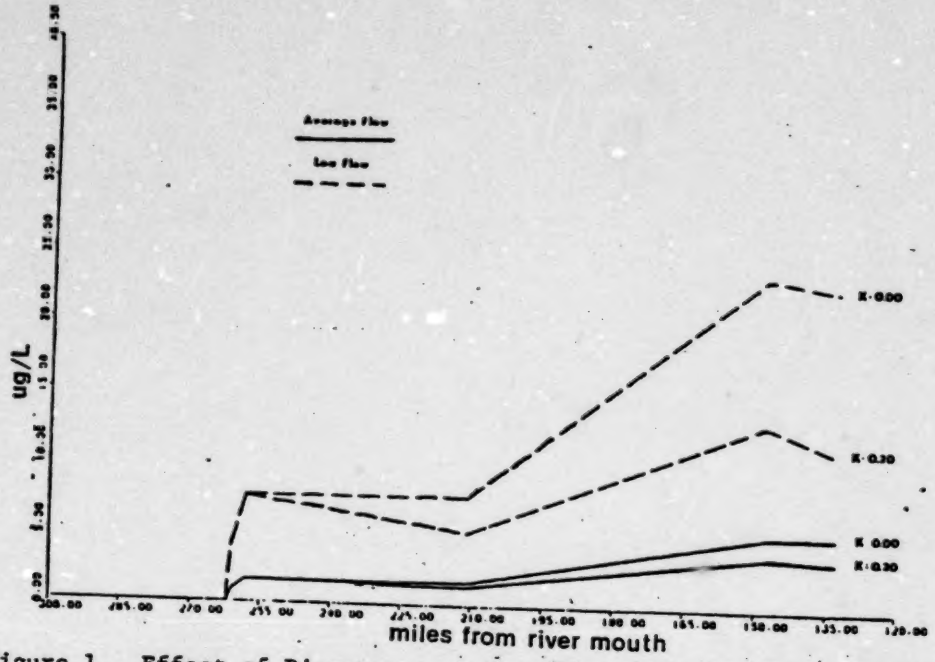

Figure 1. Effect of Disappearance Rate(K) and Flow on Dichloroethane Concentrations

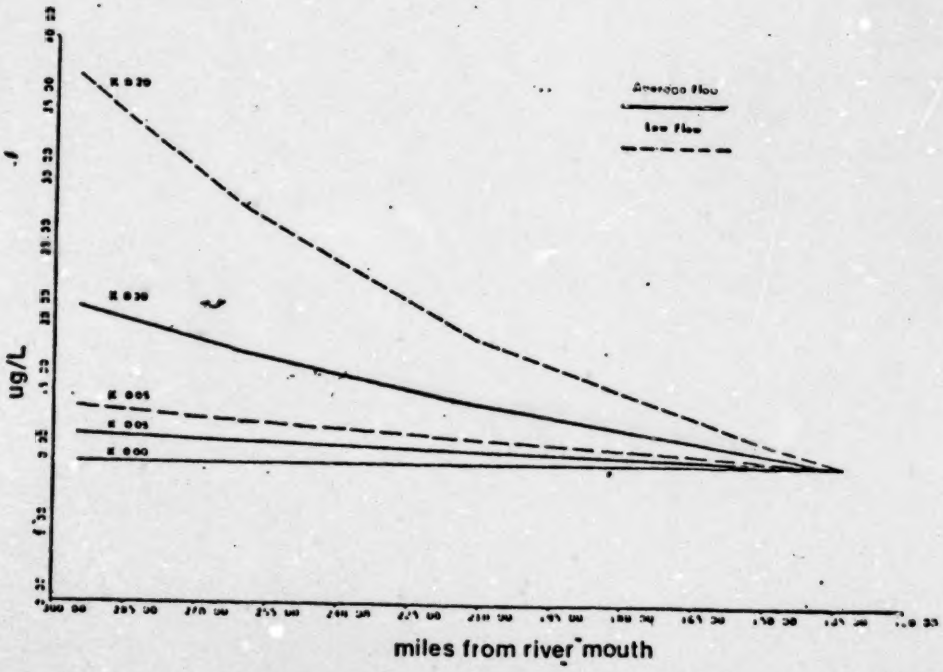

Figure 2. Upstream Directed Concentration Profiles for the Lower Mississippi River

Analyses of carcinogenic pollutants proceed differently from the previous analyses for toxic and organoleptic pollutants. When assessing risks posed by carcinogens, no single value signifies that a health hazard exists for each pollutant. Rather, the Water Quality Criteria describe the carcinogenicity at the 1×10^{-5} risk level (4). These values can be used to calculate a community's expected death rate per pollutant per year.

As expected, the overall number of expected deaths are lower at high flow because of the greater dilution of the pollutants at 220,000 cfs. However, a few carcinogens do have downstream risk levels at high flow that exceed those at average and low flow. Though the total expected deaths are lower at high flow than at average and low flows, a few individual pollutants exhibit higher concentrations because of their disappearance rates, allowing more decay at average and low flow during the longer time of travel. The overall expected death rates at two utilities are lower at low-flow than at the other rates. These results corroborate the findings for the Lower Mississippi River study and points to the usefulness of such a modeling approach.

CONCLUSIONS

Although the two case studies utilized different sources of data and mathematical techniques to simulate pollutant concentrations, the methodology of using such data and techniques is an important step in closing the gap that often exists between water pollution control strategies and water consumption. The toxic screening methodology lends itself well to many water quality management objectives, whether it is the setting up of a monitoring program or risk assessment to industrial discharges.

The quality of the screening results will be largely determined by the quality of the input data regarding the types and quantities of contaminants being discharged and the specificity with which the disappearance rate can be defined for each contaminant. The user's objectives should influence which of the many available models should be selected.

The case studies indicated several areas where additional research or data would improve the applicability of the approach. These areas included an improved understanding of the within-stream kinetics and the rate coefficients controlling the kinetics, and more specific data on the discharge characteristics of major dischargers.

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